Damage Analysis and Repair in Overhaul Motor Pump Water Treatment Plant (WTP) PT Petrokimia Gresik Sub Babat Lamongan Plant using FMEA Method

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***Abstract*—In the Water Treatment Plant (WTP) industry, motor pump maintenance is very important to maintain system performance. PT Petrokimia Gresik Sub Babat Lamongan Plant faces challenges in maintaining motor pumps that are crucial to their operations. To improve maintenance and reduce failures, a damage analysis was conducted using the Failure Mode and Effect Analysis (FMEA) method. This study aims to evaluate the potential for motor pump damage by identifying various failure modes, their impacts, and appropriate repair steps. FMEA is used to assess the risk of each failure mode, focusing on early detection and repair recommendations to improve motor pump reliability and efficiency. From 430 data analyzed, several main failure modes were found: lights out (27.6%), motor cable broken (19.6%), Motor fault (17.3%), crane jammed (9.2%), and pump jammed (6.9%). Other damages such as broken light switches, oil leaks, and abnormal sounds have a smaller percentage. The average Severity value of 6.75, Occurrence 4.5, Detection 5, and the highest Risk Priority Number (RPN) value of 252 were found in Motor Fault mode, indicating that Motor fault is the biggest risk that must be the main priority in handling and repair.**

Keywords—damage analysis, repair, motor pump, water treatment plant (WTP), FMEA

I. INTRODUCTION

The WTP industry plays an important role in maintaining the availability of clean water and running a quality water treatment process for the needs of various industrial sectors. The WTP system not only processes water for human consumption, but also supports various industrial processes, from pharmaceutical production to chemical product manufacturing. [1]. Amidst the complexity of industrial operations, motor pumps play a vital role in ensuring efficient and regular water circulation within the system. PT Petrokimia Gresik Sub Babat Lamongan Plant, as one of the entities operating in the chemical industry, relies on a reliable WTP system to support the production process and maintain the quality of the final product. [2]. Although motor pumps play a very important role, the challenge of maintaining and ensuring their optimal performance is often a major focus for companies such as PT Petrokimia Gresik. Motor pump failure can cause serious disruptions to operations, cause financially damaging downtime, and even threaten the reliability of the entire system.

In line with the importance of motor pump maintenance, PT Petrokimia Gresik faces an urgent need to conduct an in-depth evaluation of the condition of the motor pumps in their WTP. This drives the need for a comprehensive and systematic analysis of potential damage, as well as the implementation of effective repair strategies to improve reliability, minimize downtime, and optimize motor pump performance.

Factors that can cause damage to the WTP pump motor include wear of mechanical components, leaks that are not detected in a timely manner, pump system failures, or errors in maintenance. Over time, these factors can trigger various failure modes that can have a significant impact on the operation of the WTP and the overall production process. [3]. Therefore, this study has great relevance in helping PT Petrokimia Gresik to conduct an in-depth evaluation of their WTP motor pump condition. Comprehensive analysis using FMEA method is expected to identify risks associated with motor pump failure and provide strategic and appropriate repair recommendations to maintain motor pump performance in the long term.

II. MATERIALS AND METHODS

A. 3 Phase Electric Motor

Induction motors are the most widely used alternating current (AC) electric motors in the modern era. The name comes from the fact that this motor works based on the induction of the stator magnetic field to its rotor, where the rotor current of this motor is not obtained from a specific source, but is a current that is induced as a result of the relative difference between the rotor rotation and the rotating magnetic field produced by the stator current. Induction motors are widely used in everyday life both in industry and in households. Commonly used induction motors are 3-phase induction motors and 1-phase induction motors. 3-phase induction motors are operated on 3-phase power systems and are widely used in various industrial fields with large capacities. 1-phase induction motors are operated on 1-phase power systems and are widely used especially for household appliances such as fans, refrigerators, water pumps, washing machines and so on because 1-phase induction motors have low output power. [4].

B. Maintenance & Overhaul

Damage analysis and repair in the motor pump overhaul process at WTP is an in-depth study that aims to identify, analyze, and repair any damage or performance degradation that occurs to the water pump motor at the water treatment facility. [5]. The following are the stages carried out in the maintenance and overhaul process:

1. Damage Analysis

The initial stage of the analysis is to identify any damage or problems experienced by the motor pump. This can include leaks, decreased performance, component wear, or other disturbances that affect the operation of the motor pump. After identifying the problem, an in-depth inspection is carried out. Through visual inspection, functional testing, performance measurements, and component inspection, a detailed analysis of the condition of the motor pump is carried out to identify the root cause of any possible problems.

2. Improvements in Overhaul

Once the damage has been successfully analyzed, extensive repairs are carried out. This may include replacing damaged components, adjusting, structural repairs, or rejuvenating worn parts. The purpose of an overhaul is to ensure the motor pump is operating at optimum performance. Therefore, steps need to be taken to improve performance, improve reliability, and reduce the risk of future failures.

3. Testing and Verification

After the repair, a complete functional test is carried out to ensure that the pump motor is operating properly according to the desired specifications. The overhaul process is followed by continuous monitoring to ensure Table performance and evaluation of the effectiveness of the repairs that have been made.

4. Prevention and Recommendations

Based on the analysis of damage and repairs in the overhaul that has been carried out, recommendations are given to prevent similar problems in the future. This can be advice regarding preventive maintenance schedules or improvements to system design. Thus minimizing long-term risks.

C. *Water Treatment Plant (WTP)*

Water Treatment Plant (WTP) or Water Treatment Installation (IPA) is the main system for clean water treatment. Water Treatment Installation has systems or parts that play an important role in creating clean water. The systems in the Water Treatment Installation are well-organized because one system is closely related to another. In principle, there are 3 types of systems in the Water Treatment Installation, namely the Intake Water System (Incoming Water System), Water Treatment Plant (Water Treatment Installation), and Reservoir (Water Reservoir). In this article, we will discuss one of the systems in the Water Treatment System, namely the WTP system [6].

WTP consists of several gradual processes, namely the Pre-sedimentation, Coagulation, Flocculation, Sedimentation, Filtration, and Disinfection processes.

D. *Failure Mode and Effects Analysis (FMEA)*

FMEA is a systematic method used to identify, evaluate, and reduce potential failures, risks, and consequences of failures that may occur in a system, product, or process. This method is used in various industries, including manufacturing, engineering, automotive, medical, and other industries to perform an in-depth analysis of the failure modes that can occur in a component, equipment, or system, and to assess their potential impact. [7].

FMEA aims to understand and reduce the risk of failure before the problem occurs, by identifying possible failure modes, analyzing how often the failure might occur, assessing its impact on the system or product, and evaluating the severity, frequency of occurrence, and the possibility of detecting the failure before it has a major impact. FMEA is a method of evaluating the possibility of a failure of a system, design, process or service to create handling steps. In this study, FMEA was conducted to see the risks that might occur in the operation of damage and repair in the WTP motor pump overhaul in the company. In this case there are three things that help determine the disturbance, including:

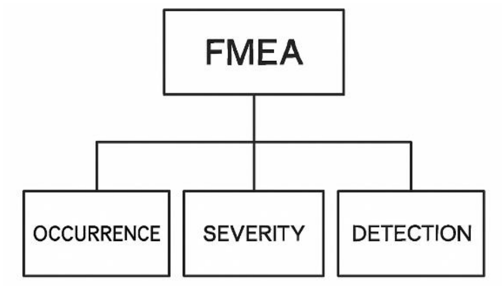

Figure 1. FMEA Parameter Scheme

1. Frequency (Occurrence)

In determining this occurrence, it can be determined how much disruption can cause a failure in maintenance operations and factory operational activities.

2. Severity of Damage

In determining the level of damage (severity), it can be determined how serious the damage is resulting from the process failure in terms of maintenance operations and factory operational activities.

3. Detection Level

In determining this level of detection, it can be determined how the failure can be known before it occurs. The level of detection can also be influenced by the number of controls that regulate the process. The more controls and procedures that regulate the operational handling system of maintenance and factory operational activities, the higher the level of failure detection is expected to be.

III. Results and Discussion

The data collection process for damage analysis and repairs in the overhaul of motor pumps at WTP PT Petrokimia Gresik is carried out with systematic steps using the FMEA method. This method aims to identify potential failure modes, causes, impacts, and plan the necessary corrective actions. Data collection was carried out on the OUTSTANDING NOTIFICATION PA BABAT document in 2021 to 2023 with a total of 430 damage and repair data. Researchers will carry out 9 stages to determine the FMEA analysis, as in Figure 2 below:

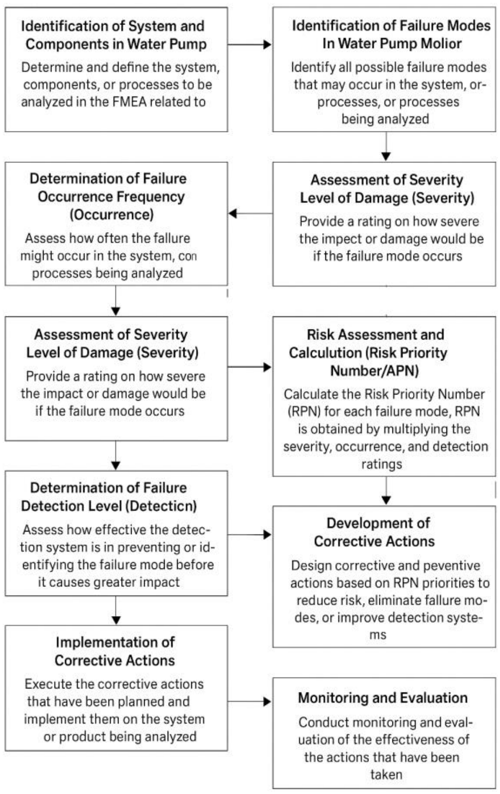

Figure 2. FMEA analysis process flow that has been carried out by researchers

From Figure 2, it is known that the damage analysis and repair process begin with the identification of systems and components in the water pump motor. At this stage, the research team determines and defines the systems, components, or processes to be analyzed in the FMEA related to the motor. After the system is identified, the next step is to identify the failure mode in the pump motor. Here, all possible failure modes that may occur in the system, component, or process being analyzed are thoroughly identified. After the failure mode is identified, the team continues with determining the severity of the damage. At this stage, an assessment is made of the severity or impact that will occur if each failure mode occurs. Furthermore, determining the frequency of failure (occurrence), this stage aims to assess how often the possibility of failure can occur in the system, component, or process being analyzed. The stage is continued by determining the level of failure detection (detection). This stage aims to assess how effective the detection system is in preventing or detecting the failure mode before it causes a greater impact. After all assessments are carried out, the next step is the calculation and assessment of risk (Risk Priority Number/RPN). RPN is calculated by multiplying the severity, frequency of occurrence, and detection level for each failure mode. Based on the results of the RPN calculation, then develop corrective actions. These actions are designed and prioritized based on the highest RPN to reduce risk, eliminate failure modes, or improve detection systems. After the corrective action plan is prepared, the next step is the implementation of corrective actions. At this stage, the planned corrective actions are implemented and implemented on the system or product being analyzed. The process ends with monitoring and evaluation, this stage monitors and evaluates the effectiveness of the corrective actions that have been taken to ensure that the actions are successful in reducing risk and increasing system reliability. From the results of the FMEA data analysis, the following data was obtained:

A. *Damage Identification*

Identification of damage mode is the initial step in FMEA analysis which aims to classify various types of damage that occur in the motor based on the available notification data, from 430 data obtained not all data are filled in completely only 334 data contain a description of the type of damage (notification description column). From the data obtained, the damage mode is identified by referring to the recorded damage notification description.

Based on descriptive analysis, several main damage modes were found that frequently occur, including:

1. Motor cable is broken or not long enough
2. *Motor fault* (burned, stalled, won't start)
3. The lights are out (room lights, street lights, bathroom lights).
4. Crane is jammed or cannot operate
5. Pump is stuck or won't start
6. The light switch is broken
7. Oil leak on the motor
8. Noise abnormalities in motor

Table 1 below summarizes the frequency of occurrence of failure modes based on notification data.

Table1. Frequency of Appearance

Damage Mode	Frequency	Percentage (%)
Motor cable broken	85	19.77
Motor Fault	75	17.44
Lights out	120	27.91
Crane jammed	40	9.30
Pump jammed	30	6.98
The light switch is broken	25	5.81
Oil leak	20	4.65
Sound disorders	15	3.49
Etc	20	4.65
Total	430	100.00

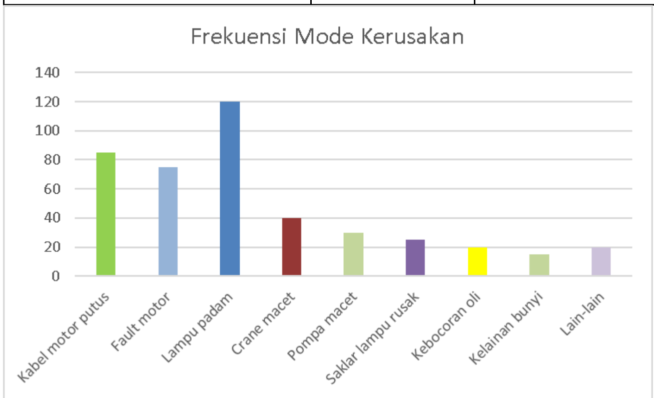

Figure 3. Frequency of Damage Mode

B. Severity Analysis

Severity is a parameter that indicates the impact of a damage mode on the operation and safety of the equipment. Severity assessment is carried out on a scale of 1 to 10, where a value of 10 indicates a very severe and critical impact. Based on the analyzed data, the following is the distribution of severity values for various damage modes:

Table2. Average Severity

Damage Mode	Average Severity	Impact Description
Motor cable broken	7	Moderate to severe operational disruption
Motor Fault	9	Critical damage, causing the motor to not function
Lights out	5	Minor disturbance, affecting lighting
Crane jammed	8	Severe disruption, hampering the production process
Pump jammed	8	Severe disturbance, interfering with fluid flow
The light switch is broken	4	Minor glitch, easy to fix
Oil leak	7	Potential for further damage if left untreated
Sound disorders	6	Early indication of damage, inspection required
Overall Average Damage Mode	6.75	Moderate impact, affects function but is still tolerable

This severity assessment is the basis for determining handling priorities, where damage with high severity must be handled immediately to avoid greater losses.

C. Occurrence Analysis

Occurrence or frequency of occurrence indicates how often a damage mode occurs in the observation period. This parameter is also assessed on a scale of 1 to 10, where a value of 10 indicates a very high frequency of occurrence. From the analyzed data, here are the average occurrence values for several major damage modes:

Table3. Average Occurrence

Damage Mode	Average Occurrence	Frequency Description
Motor cable broken	6	Happens quite often
Motor Fault	4	Occurs rarely but has a big impact
Lights out	7	Happens very often
Crane jammed	3	Occurs rarely
Pump jammed	4	Occurs rarely
The light switch is broken	5	Occurs in progress
Oil leak	3	Occurs rarely
Sound disorders	4	Occurs rarely
Overall Average Damage Mode	4.5	Failures occur with moderate frequency, quite often.

The blackout has the highest occurrence value, indicating that this disturbance occurs most frequently. This is in line with the frequency data of the previously identified damage modes. This occurrence analysis is important to identify the damage modes that occur frequently so that ongoing preventive actions can be taken to reduce the frequency of damage.

D. Analysis Detection

Detection is the ability of the monitoring and maintenance system to detect a failure mode before it has a further impact. This parameter is also rated on a scale of 1 to 10, where a value of 10 indicates a very low level of detection (difficult to detect). The following is the average detection value for the failure modes analyzed:

Table4. Average Detection

Damage Mode	Average Detection	Detection Description
Motor cable broken	5	Moderate detection, can be detected before serious damage
Motor Fault	7	Low detection, often occurs suddenly
Lights out	3	High detection, easy to find out
Crane jammed	6	Low detection, hard to predict
Pump jammed	6	Low detection, hard to predict
The light switch is broken	4	Moderate detection, can be known by routine inspection
Oil leak	5	Moderate detection, need regular check-up
Sound disorders	4	Moderate detection, can be known from the sound
Overall Average Damage Mode	5	Failure can be detected with moderate difficulty

The fault mode of the lamp out has the lowest detection value, which means it is easy to detect and can be handled immediately. In contrast, the Motor fault has the highest detection value, indicating that this fault is difficult to detect before it occurs.

E. RPN Calculation

Risk Priority Number (RPN) is the result of multiplying the Severity, Occurrence, and Detection values. RPN is used to determine the priority of handling damage based on the level of risk generated. The higher the RPN value, the higher the priority of handling that must be done.
The RPN calculation formula is as follows:

$$RPN = Severity\ x\ Occurrence\ x\ times\ Detection \quad (1)$$

Table5. RPN Calculation

Damage Mode	*Severity*	*Occurrence*	*Detection*	RPN	Handling Priority
Motor cable broken	7	6	5	210	Tall
Motor Fault	9	4	7	252	Very high
Lights out	5	7	3	105	Currently
Crane jammed	8	3	6	144	Tall

Damage Mode	*Severity*	*Occurrence*	*Detection*	RPN	Handling Priority
Pump jammed	8	4	6	192	Tall
The light switch is broken	4	5	4	80	Low
Oil leak	7	3	5	105	Currently
Sound disorders	6	4	4	96	Low

From the Table above, Motor fault has the highest RPN value of 252, which indicates that this damage should be a top priority in handling. Broken motor cables and stuck pumps also have high RPN values so they need special attention. This RPN calculation is the basis for decision making to determine the most effective and efficient repair and prevention actions.

F. Recommendation

Based on the results of the FMEA analysis that has been carried out, it can be concluded that the most critical and high-risk damage modes are motor fault, broken motor cable, and stuck pump. These three damage modes have high RPN values, indicating a major impact on operations and a significant frequency of occurrence.

Motor fault damage has the highest severity because it can cause the motor to not function at all, thus disrupting the overall production process. However, detection for this mode is still low, which means that the current monitoring system is not optimal in detecting this damage early. Therefore, it is necessary to improve the monitoring system, such as the use of temperature sensors, vibrations, or IoT-based predictive maintenance systems to detect early signs of motor damage.

Broken motor cables are also a common problem and have a high RPN value. This damage can be prevented by conducting regular inspections and replacing worn or out-of-spec cables. In addition, technician training and improving electrical installation standards are also very important to reduce the risk of cable damage.

For the lamp failure mode, although the frequency of occurrence is high, the severity and RPN values are relatively lower. Handling of this damage can be done with routine maintenance and periodic lamp replacement. A good detection system also makes it easier to identify lamp damage so that it can be repaired immediately.

Proposed corrective action recommendations based on FMEA results include:

1. Improved monitoring and early detection systems for motorcycles, including the use of sensor technology and predictive systems.
2. Schedule regular inspection and maintenance of motor cables to prevent sudden damage.
3. Training technicians in the installation and repair of motors and other electrical components.
4. Replacement of components that are worn out or do not meet quality standards.
5. Improved documentation and reporting of defects to facilitate analysis and follow-up.

By implementing these recommendations, it is expected that the risk of motor damage can be minimized, thereby increasing equipment reliability and overall operational efficiency. This FMEA analysis provides a comprehensive picture of the condition of motor equipment and becomes a strong basis for decision making in maintenance management. Implementing appropriate actions based on risk priorities will help reduce downtime, repair costs, and improve work safety.

IV. Conclusion

From field maintenance and repair data during the period 2021 to 2023, with a total of 430 data entries analyzed in depth. Based on the FMEA analysis that has been carried out, there are several main damage modes that often occur in electric motor equipment, namely: Lights out (27.6% of total damage), Motor cable broken (19.6%), Motor fault (17.3%), Crane jammed (9.2%), Pump jammed (6.9%), Broken light switch, oil leaks, and sound abnormalities, each of which has a smaller percentage. This identification provides a clear picture of the types of damage that occur most often and are the main focus in repair and prevention efforts.

The average Severity value of all damage modes is 6.75, indicating that the damage that occurs has a fairly serious impact on the operation and safety of the equipment. The average Occurrence value is 4.5, indicating that the damage occurs with moderate to quite frequent frequency. The average Detection value is 5, indicating that the current monitoring system has moderate detection capability, but still needs to be improved so that damage can be detected earlier. This data is the basis for determining the priority of handling and developing a more effective monitoring system.

Risk Priority Number (RPN) Calculation The highest RPN value was found in the Motor fault damage mode with a value of 252, which is the result of multiplying Severity (9), Occurrence (4), and Detection (7). This value indicates that Motor fault is the highest risk that must be the main priority in handling and repair. In addition, the motor cable breakage and pump jammed damage modes also have high RPN values, so they need special attention in the maintenance program.

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